METHOD AND APPARATUS TO REDUCE OFF-TRACK WRITES DUE TO COIL POPPING

by

Wallis A. Dague
David R. Lapp
David P. McReynolds

METHOD AND APPARATUS TO REDUCE OFF-TRACK WRITES DUE TO COIL POPPING

Related Applications

This application claims priority of United States provisional application Serial Number 60/419,752, filed October 18, 2002.

Field of the Invention

This application relates generally to data storage devices, and more particularly to a method and apparatus to reduce off-track writes in a disc drive due to coil popping.

Background of the Invention

The storage medium for a disc drive is a flat, circular disc capable of retaining localized magnetic fields. The data is arranged on the disc in concentric, circular paths known as tracks. A disc drive uses a magnetically sensitive head (transducer) to detect the data. The transducer is mounted upon an actuator, which is attached to a voice coil. The voice coil is immersed in a magnetic field generated by permanent magnets. This causes the actuator to move when a current is applied to the actuator.

A cost-effective and dynamically robust way to attach the voice coil to the actuator is to use an over-mold of structural plastic. The voice coil is held in a fantail section of the actuator, and the over-mold surrounds the voice coil and the fantail section of the actuator. However, when an over-mold is used to attach the voice coil to the actuator, a phenomenon known as "coil popping" can occur.

Coil popping occurs when the over-mold separates from the actuator as a result of the over-mold and the actuator each having a different coefficient of thermal expansion. During normal seek operations, current though the coil causes the temperature of the actuator to increase. This temperature increase causes the over-mold and the actuator to both expand at different rates. The actuator quickly decreases in temperature when the actuator stops at a desired location in order to perform a read or write operation, causing the actuator and the over-mold to both

quickly shrink at different rates, which creates stress at the interfaces between the actuator and the over-mold. Coil popping is a physical shift that occurs in response to the stress.

When coil popping occurs, the actuator shudders, driving the transducer off track. If coil popping occurs during a write process, then data stored on adjacent tracks can be corrupted.

Accordingly there is a need for a method and apparatus to reduce off-track writes due to the phenomenon of coil popping.

Summary of the Invention

Against this backdrop, embodiments of the present invention has been developed. According to one exemplary embodiment, thermal restraint features are included in the fantail section of the actuator. The thermal restraint features are located on the fantail section to reduce the length of an interface between the over-mold and the actuator acted upon by shear forces generated by the mismatch of the coefficients of thermal expansion between the over-mold and the actuator. The thermal restraint features operate to reduce the effect of the thermal stress in order to prevent popping. According to one exemplary embodiment, the thermal restraint features are one or more spaced holes along each leg of the fantail section of the actuator that extend through the fantail section of the actuator. Over-mold material fills these holes and effectively minimizes coil popping from occurring thus minimizing off-track writes due to coil popping phenomenon.

These and various other features as well as advantages which characterize the present invention will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

FIG. 1 is a plan view of a disc drive incorporating an embodiment of the present invention, with portions broken away to show the primary internal components.

FIG. 2 is an enlarged plan view of a fantail portion of an actuator incorporating an embodiment of the present invention, with the voice coil and over-mold depicted in dashed lines.

FIG. 3 is a perspective view of the fantail portion of the actuator shown in FIG. 2.

FIG. 4 is a perspective view of an alternative embodiment of the fantail portion of the actuator shown in FIG. 2.

Detailed Description

A disc drive **100** constructed in accordance with a preferred embodiment of the present invention is shown in FIG. **1**. The disc drive **100** includes a base **102** to which various components of the disc drive **100** are mounted. A top cover **104**, shown partially cut away, cooperates with the base **102** to form an internal, sealed environment for the disc drive in a conventional manner. The components include a spindle motor **106** which rotates one or more discs **108** at a constant high speed. Information is written to and read from tracks on the discs **108** through the use of an actuator assembly **110**, which rotates during a seek operation about a bearing shaft assembly **112** positioned adjacent the discs **108**. The actuator assembly **110** includes a plurality of actuator arms **114** which extend towards the discs **108**, with one or more flexures **116** extending from each of the actuator arms **114**. Mounted at the distal end of each of the flexures **116** is a head **118** which includes a fluid bearing slider enabling the head **118** to fly in close proximity above the corresponding surface of the associated disc **108**.

During a seek operation, the track position of the heads **118** is controlled through the use of a voice coil motor (VCM) **124**, which typically includes a voice coil **126** attached to the actuator assembly **110**, as well as one or more permanent magnets **128** which establish a magnetic field in which the coil **126** is immersed. The controlled application of current to the voice coil **126** causes magnetic interaction between the permanent magnets **128** and the voice coil **126** so that the coil voice **126** moves in accordance with the well known Lorentz relationship. As the voice coil **126** moves, the actuator assembly **110** pivots about the bearing shaft assembly **112**, and the heads **118** are caused to move across the surfaces of the discs **108**. The voice coil 126 is covered by an over-mold 140.

The spindle motor **116** is typically de-energized when the disc drive **100** is not in use for extended periods of time. The heads **118** are moved over park zones

120 near the inner diameter of the discs **108** in the embodiment shown when the drive motor is de-energized. The heads **118** are secured over the park zones **120** through the use of an actuator latch arrangement, which prevents inadvertent rotation of the actuator assembly **110** when the heads are parked.

A flex assembly **130** provides the requisite electrical connection paths for the actuator assembly **110** while allowing pivotal movement of the actuator assembly **110** during operation. The flex assembly includes a printed circuit board **132** to which head wires (not shown) are connected; the head wires being routed along the actuator arms **114** and the flexures **116** to the heads **118**. The printed circuit board **132** typically includes circuitry for controlling the write currents applied to the heads **118** during a write operation and a preamplifier for amplifying read signals generated by the heads **118** during a read operation. The flex assembly terminates at a flex bracket **134** for communication through the base deck **102** to a disc drive printed circuit board (not shown) mounted to the bottom side of the disc drive **100**.

FIG. 2 is an enlarged, partial plan view of an actuator assembly **110** incorporating an embodiment of the present invention, with the voice coil and over-mold depicted in dashed lines. The actuator assembly **110** includes an actuator body **201**, the voice coil **126**, and the over-mold **140**. The actuator body **201** includes a fantail portion **204**, extending opposite the actuator arms **114**. The fantail portion **204** has two spaced apart legs **206** and **208**, forming a yoke for holding the voice coil **126**. Leg **206** includes a bias bar **210** that is press fit through the fantail portion **204**. The leg **206** also includes thermal restraint features **220** and **222**, spaced along the length of the leg **206**. The leg **208** includes insulated connector pins **212** and **214**. The leg **208** also includes thermal restraint features **224** and **226**, spaced along the leg **208**. The voice coil **126**, positioned between the legs **206** and **208**, and the over-mold **140**, formed around and over the legs **206** and **208**, are shown with dotted lines so that the legs **206** and **208** within the over-mold **140** can be seen.

The voice coil **126** is configured to move (rotate) the actuator body **201** when a current is applied to the voice coil **126** via pins **212** and **214**. The over-mold **140** surrounds the legs **206** and **208**, and the voice coil **126** so that the voice coil **126** is coupled to the actuator body **201**.

The bias bar **210** is a piece of steel that, under the influence of the magnetic field produced by magnets **128**, provides a bias force on the actuator body **201** in a clockwise direction. Pins **212** and **214** are coil termination pins that are covered with a plastic insulator and are thus insulated from the fantail portion **204**. Beginning and end wires of the voice coil **126** are coupled to pins **212** and **214**. The voice coil **126** receives current from the disc drive servo-control system (not shown) via pins **212** and **214** for moving the actuator. The bias bar **210** and pins **212** and **214** do not limit coil popping, because they are positioned too close to the proximal end of the legs **206** and **208** to effectively limit the length of the legs **206** and **208**.

FIG. 3 is an enlarged separate perspective view of the fantail section **204** of the actuator body **201** shown in FIG. 2. Figure 3 shows the actuator body **201** before the over-mold **140** and certain other features are added. The leg **206** has a hole **310** for receiving the bias bar **210** (shown in FIG. 2). The leg **206** also has holes **220** and **222**. The leg **208** has holes **312** and **314** for receiving pins **212** and **214** (shown in FIG. 2) respectively. The leg **208** also has holes **224** and **226**. The bias bar **212** and pins **214** and **216** are installed before over-molding. When the over-mold **140** is molded onto the actuator body **201**, the over-mold **140** surrounds the bias bar **212**, and pins **214** and **216**. According to an example in which the thermal restraint features (**220, 222, 224,** and **226**) are holes, the over-mold **140** extends through holes **220, 222, 224,** and **226**, interlocking the over-mold to the legs **206** and **208**. This interlock effectively divides the legs **206** and **208** into short lengths in which relative movement over-mold with respect to the fantail **204** is substantially precluded. This minimizes occurrences of coil popping.

FIG. 4 is an enlarged separate perspective view of an alternative embodiment of the fantail section **204** of the actuator body **201** shown in FIG. 2. In FIG. 4, thermal restraint features **420, 422, 424,** and **426** are pins that extend through the fantail portion **204** and extend vertically from the fantail portion **204**. Pins **420, 422, 424,** and **426** may be press fit in place, glued, or otherwise fastened to the fantail **204**. Alternatively, pins **420, 422, 424,** and **426**, may be integrally formed in the fantail portion **204**.

In the embodiment shown in FIG. 3, thermal restraint features **220, 222, 224,** and **226** are holes in the actuator that extend through the fantail portion **204**.

The over-mold **140** extends through holes **220**, **222**, **224**, and **226**. Alternatively, as shown in FIG. 4, thermal restraint features **420**, **422**, **424**, and **426** may be pins that extend vertically from the actuator body **201**. According to yet another alternative, thermal restraint features **220** and **222** may be bridges or walls positioned across the width of the leg **206**, and thermal restraint features **224** and **226** may be bridges or walls positioned across the width of the leg **208**.

The over-mold **140** engages the thermal restraint features (**220**, **222**, **224**, and **226** or **420**, **422**, **424**, and **426**) to prevent the over-mold **140** from separating from the actuator body **201** as a result of the over-mold **140** and the actuator body **201** each having a different coefficient of thermal expansion. The thermal restraint features are located such that the length of the effective interface between the over-mold **140** and the actuator body **201** that is acted upon by shear forces caused by the mismatch of thermal coefficients of expansion between the actuator body **201** and the over-mold **140** is reduced. Thermal loads produced during a temperature change are transferred to the structure of the fantail portion **204** without substantial slippage. This reduces the effects of the thermal stress in order to limit coil popping.

The presence of a thermal restraint feature on the legs of the fantail portion prevents thermal expansion of the components beyond the location of the thermal restraint feature. Since the amount of thermal expansion is proportional to length, the presence of a thermal restraint feature reduces the effective length of the leg. For example, if a leg had one thermal restraint feature approximately halfway between the proximal and distal ends of the leg, the effective length of the leg would be reduced by half, and the thermal expansion of each section would be reduced by approximately half. If a leg has two thermal restraint features that divide the leg into approximately three equal parts, then thermal expansion of each section is reduced to approximately one third. (This is the configuration depicted in FIG. 2, FIG. 3, and FIG. 4). This configuration significantly decreases effects of thermal stresses caused by the mismatch of thermal coefficients of expansion between the actuator body **201** and the over-mold **140**, and therefore significantly limits thermal popping. In contrast, a hole or a pin that is near the distal or proximal end of a leg of a fantail portion of an actuator does not act as a thermal restraint feature, because it has little or no effect on thermal expansion.

Although round thermal restraint features are shown in FIG. 2, FIG. 3, and FIG. 4, any shape may be used for the thermal restraint features, as the shape of the thermal restraint feature makes no appreciable difference with regard to coil popping. However, it may be more cost effective to use a round shape.

The actuator body **201** may be composed of aluminum. Alternatively, the actuator body **201** may be composed of another metal or non-metallic material.

The over-mold **140** may be composed of structural plastic. Coil popping may be reduced by utilizing an over-mold material having a coefficient of thermal expansion that closely matches the coefficient of thermal expansion of the material that the actuator is composed of. For example, the vendor RTP Company of Winona, MN supplies a material called 1399x94017J, and the supplier LNP ENGINEERING PLASTICS, INC. of Exton, PA supplies a material called PDX-01787CCSGN4A421. PDX-01787CCSGN4A421 and 1399x94017J have coefficients of thermal expansion that more closely match the coefficient of thermal expansion of aluminum.

It will be clear that the present invention is well adapted to attain the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment has been described for purposes of this disclosure, various changes and modifications may be made which are well within the scope of the present invention. For example, a variety of features shapes may be used for the thermal restraint features. Also, other configurations of the thermal restraint features are possible. For example, each of the legs may have more or less thermal restraint feature than shown. As another example, the positioning of the thermal restraint features may be different, as long as the thermal restraint features are positioned to reduce the effective length of the leg that it is on. Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed and as defined in the appended claims.